§21. Neoclassical Bootstrap Current in CHS-qa Quasi-Axisymmetric Stellarator

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In the physics design of quasi-axisymmetric stellararor CHS-qa[1,2], a bootstrap current in a finite β plasma is important because it is thought to be substantial due to tokamak-like quasi-axisymmetry. In order to investigate the effect of bootstrap current on the finite β equilibrium of CHS-qa, the code which calculates the three dimensional MHD equilibrium including neoclassical bootstrap current self-consistently in the whole collisionality range[3] has been used.

The bootstrap current density dI_{bs}/ds, rotational transform $\iota/2\pi$ and magnetic well depth in the vacuum and finite β equilibria are shown in Fig.1 for "2b32" configuration (A_p=3.2, N=2). The plasma parameters are : $T=T(0)\bullet(1\text{-}s)$, $T_e(0)$=2.0 keV, $T_i(0)$=1.5 keV, $n=n(0)\bullet(1\text{-}0.8\bullet s+1.3\bullet s^2\text{-}1.5\bullet s^3)$, $n_e(0)=n_i(0)=2.0\times10^{19}$ m^{-3} and B_t=1 T. The relatively board density profile, which is plausible in actual discharges, is chosen in this analysis. The total bootstrap current I_{bs} is evaluated to be 56 kA at $<\beta>$ of 1.2 % (β_0=2.8 %) and $\iota/2\pi$ is significantly increased (see Fig.1(b)). It is noted that in currentless equilibrium of CHS-qa, $\iota/2\pi$ decreases as β increases. The magnetic well becomes deeper, by about two times at the plasma boundary, than that in vacuum equilibrium as seen in Fig. 1(c).

Fig. 2 shows I_{bs} as a function of $<\beta>$. The calculation was made for both high n_e ($n_e(0)=1.0\times10^{20}$ m^{-3}) and low n_e ($n_e(0)=2.0\times10^{19}$ m^{-3}) cases, i.e. for different collisionality regimes at B_t of 1 T. By keeping the density and temperature profile as in Fig. 1, $T(0)$ is changed. In the low n_e plasmas, I_{bs} steeply increases as $<\beta>$ increases and reaches 100 kA when $<\beta>$ exceeds 2 %. On the other hand, in the high n_e plasmas, I_{bs} at the same $<\beta>$ is much lower than that in low n_e plasmas as expected. In order to see the effect of non-axisymmetric magnetic field components on I_{bs}, the calculation on "pure QA" is made by eliminating non-axisymmetric magnetic field components. Open circles in Fig. 2 stand for I_{bs} in the pure QA condition. I_{bs} in the pure QA is always larger, e.q. by about 40 % at $<\beta>$ of 1.2 %, than that in real QA.

The finite β equilibria with different density profiles are also calculated to see their influence on dI_{bs}/ds and resulting $\iota/2\pi$[4]. The analysis indicates that the parabolic density profile produces the reversed shear-like $\iota/2\pi$ profile in tokamaks and broad profile results in monotonously increasing $\iota/2\pi$ toward the plasma edge. This gives us the flexibility of CHS-qa experiment under a variety of $\iota/2\pi$ profiles if the density profile can be controlled by means of ECH, pellet and so on.

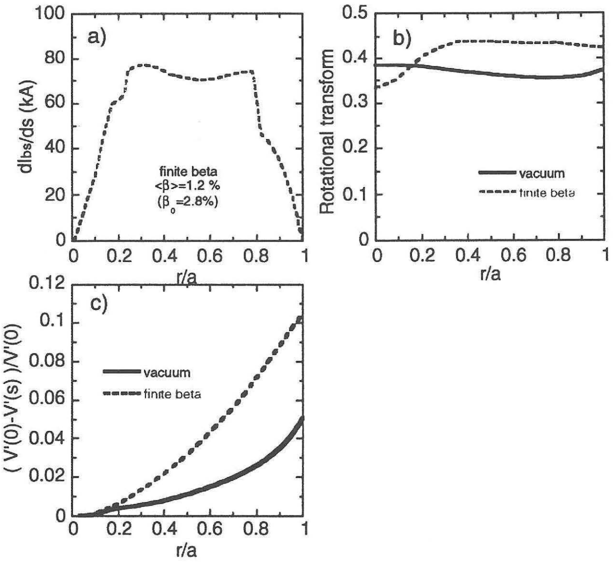

Figure 1 Bootstrap currnet in the finite β plasma of CHS-qa at B_t=1 T, a) Bootstrap current density dI_{bs}/ds, b) Rotational transform $\iota/2\pi$ in vacuum and finite β equilibrium, c) Magnetic well.

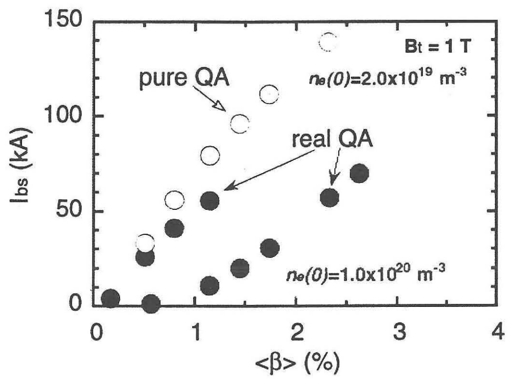

Figure 2 Total bootstrap current as a function of $<\beta>$ for different densities. Closed circles represent I_{bs} in real QA. Open circles stand for I_{bs} in pure QA.

References
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